Canadian Centre for Occupational Health and Safety

Centre canadien d'hygiène et de sécurité au travail

LIGHTING ERGONOMICS

P89-18E

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Canadian Centre for Occupational Health and Safety

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LIGHTING ERGONOMICS

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PREFACE

This publication is part of a series on ergonomics. It is prepared as a source of information for health and safety committees and others with an interest in understanding and optimizing the benefits of good workplace lighting.

See also CCOHS publication Ergonomics for Workplaces with Visual Display Terminals (P89-22E) for information on lighting for VDT workstations.

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1. INTRODUCTION

Workers receive about 85 percent of their information through their sense of sight. Good workplace lighting is essential for health and safety.

A good workplace lighting system:

- makes it easier to see in the workplace
- evenly distributes light without producing glare or shadows
- assists in creating a comfortable atmosphere
- lights up dark areas and makes them safer

Proper lighting makes all work tasks easier. The appropriate lighting, without glare or shadows, reduces eye fatigue and headaches. Good lighting eliminates shadows and highlights moving machinery and other safety hazards. It also reduces the chance of accidents and injuries from momentary blindness while the eyes adjust to brighter or darker surroundings.

The ability to see at work depends not only on lighting. It also depends on:

- time to focus on an object--fast moving objects are hard to see
- size of an object--very small objects are hard to see
- brightness--too much or too little reflected light makes objects hard to see
- contrast between an object and its immediate background--too little contrast makes it hard to distinguish an object from the background

The checklist in Appendix A provides an overview of lighting problems and their detection.

2. SOURCES OF LIGHT

Daylight

The amount of daylight inside buildings depends on the amount and direction of sunlight, cloud cover, local terrain, season, and the size, orientation and cleanliness of windows.

Tinted glass, window blinds, curtains, awnings and overhangs control the amount of daylight entering the workplace.

Daylight is desirable in the workplace providing it doesn't cause glare, too bright conditions or not enough light. But even in workplaces where daylight is available it is essential to have a good electric lighting system.

Electric Lighting

The amount of light, the colour of the light itself and the colour that objects appear vary with the type of electric lighting. The lighting must match the workplace and the task. The following are commonly used types of bulbs.*

Table 1 - Light bulbs

Type	Common Application	Efficiency	Colour Rendering**
Incandescent	homes	poor	good
Fluorescent	offices	good	fair to good
Mercury	factories offices	fair	fair to moderate
Low pressure sodium	roadway	good	poor
High pressure sodium	factories commercial	good	fair to good
Metal Halide	factories commercial	good	good

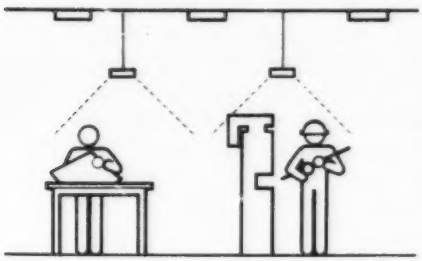
* Bulbs are referred to as lamps in technical publications.

** Colour rendering is the effect of light on the colour of objects.

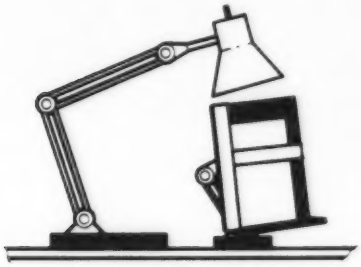
3. BASIC TYPES OF ARTIFICIAL LIGHTING

There are three basic types of lighting: general, localized-general, and local.

General lighting provides fairly uniform lighting. Ceiling fixtures light up large areas.



Localized-general lighting uses overhead fixtures in addition to ceiling fixtures to increase lighting levels for particular tasks.

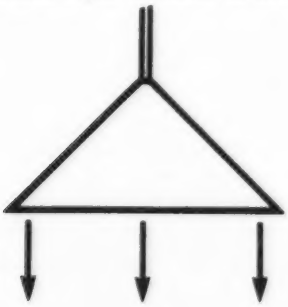


Local lighting increases light levels over the task and immediate surroundings. Local lighting often allows the user to adjust and control lighting, providing flexibility in workplace lighting.

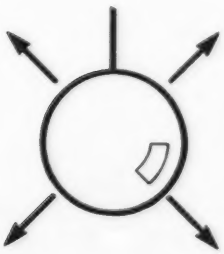
Light Fixtures*

The complete lighting unit, or light fixture, controls and distributes the light.

Various light fixtures distribute light upwards and downwards differently.



Direct light fixtures emit 90 to 100 percent of their light downward toward the work area. Direct lighting tends to create shadows.



Direct-indirect light fixtures distribute light equally upward and downward. They reflect light off the ceiling and other room surfaces. Little light is emitted horizontally so direct glare is often reduced. They are usually used in clean manufacturing areas.

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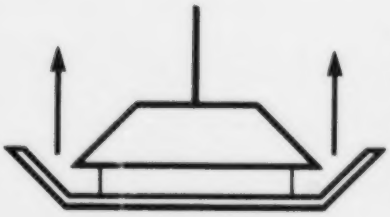
* Light fixtures are often referred to as luminaires in technical publications.



Indirect light fixtures distribute 90 to 100 percent of the light upward. The ceiling and upper walls must be clean and highly reflective so the light reaches the work area. They provide the most even illumination of all the varieties and the least direct glare. Indirect light fixtures are usually used in areas such as offices.

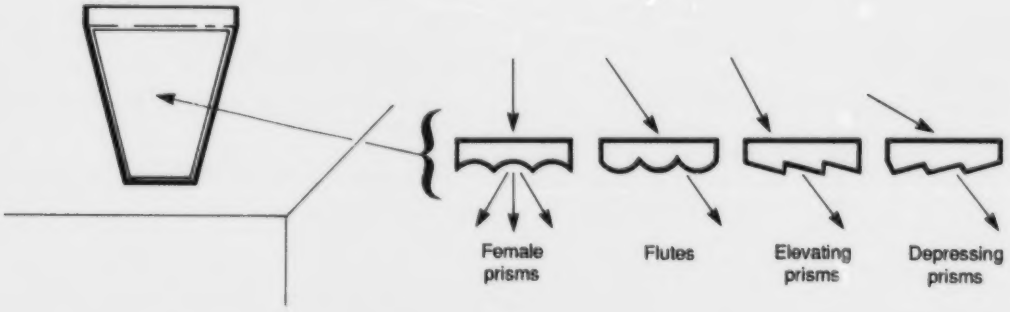
No single type of light fixture is appropriate in every situation. The amount and quality of lighting required for a particular workplace determines which light fixture is most suitable.

Shielded Light Fixtures

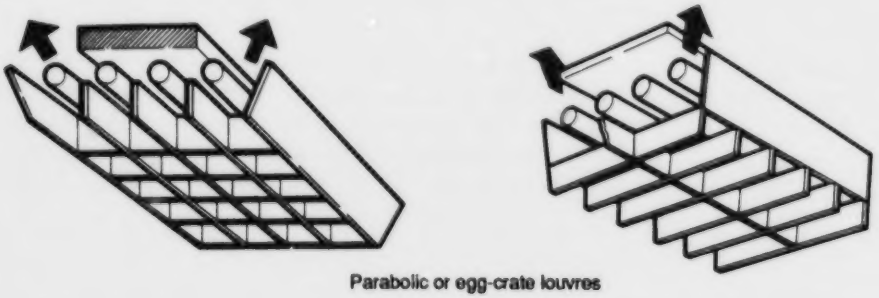
Diffusers, lenses and louvers shield bulbs from direct view helping to prevent glare and distribute light.

Diffusers are opaque or translucent glass or plastic covers. They are used on the bottom or sides of light fixtures to control brightness.

Lenses are clear or transparent glass or plastic covers. The lens design incorporates prisms and flutes to distribute light in specific ways.



Louvers are baffles that shield the bulb from view and reflect light. The baffles can be contoured to control light and decrease brightness. Parabolic louvers are specially shaped grids that concentrate and distribute light.



Parabolic or egg-crate louvres

4. LIGHT AND COLOUR

Sunlight is made up of all the colours of the rainbow spectrum--red, orange, yellow, green, blue, indigo and violet. Most electric light sources produce only some of the colours, although they may appear to be emitting "white" light. Colour appearance is different under electric light and daylight. As a result, the true colour of an object can only be determined when viewed under daylight or under light that has the same spectral composition as daylight. Full spectrum lighting reproduces the spectral characteristics of daylight.

When colour judgement is important, so is the lighting. The colour that an object appears to an observer depends upon the colour composition of the light and the colour of the light that the object reflects and absorbs. Different light sources produce light that has different colour rendering characteristics.

5. COMMON LIGHTING PROBLEMS

Poor lighting can cause several problems. Awareness of common lighting problems can help the occupational health and safety committee to detect problems. The following summarizes ways for a committee without formal training or sophisticated instrumentation to detect and solve these problems. Section 6 describes the elements of a more detailed lighting survey.

Insufficient Light

Insufficient light on work results from insufficient light from light fixtures, low reflectance levels, or shadows. A worker may misjudge the position, shape or speed of an object because of insufficient light. Eyes take time to adapt to abrupt variations in brightness, especially when going from very bright to dimly lit areas. A person cannot see detail until the eye adjusts completely.

The amount of light needed varies according to the work activity, the work environment and worker characteristics. Important factors include the type of task, the task demands for speed and accuracy, surface reflectances, and the individual worker's vision.

The amount of light falling on a surface is measured in units called lux. Depending on the factors noted above, adequate general lighting is usually between 500 and 1000 lux, measured 760 mm above the floor.* Examples of industrial and office tasks and the recommended light levels follow.

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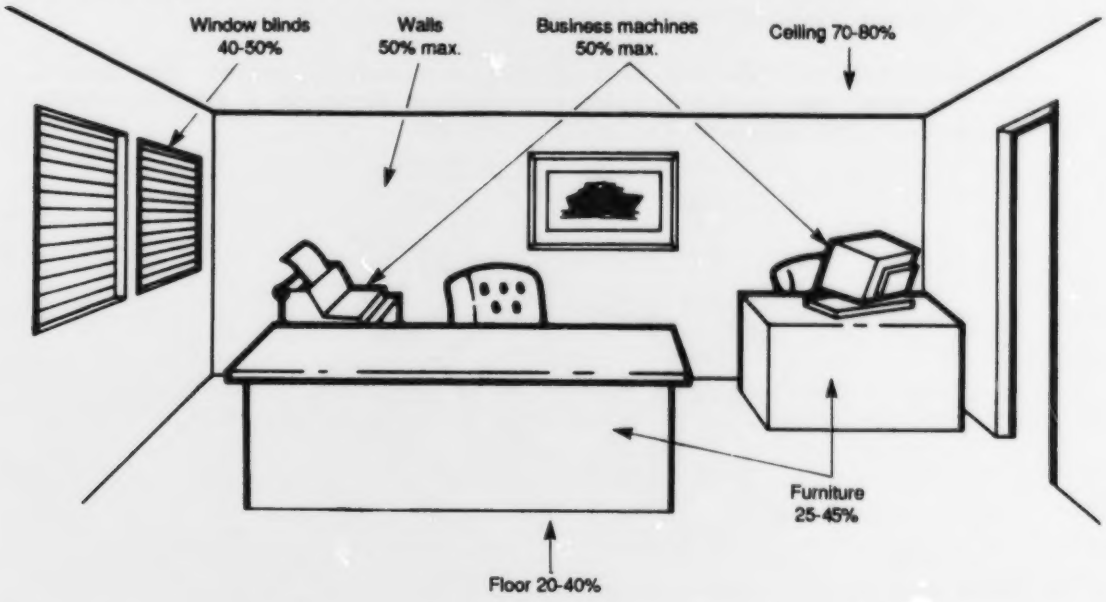
* Source: IES lighting handbook: reference volume. Kaufman, J.E. editor. New York: Illuminating Engineering Society of North America, 1987, p. 3-34.

Table 2 - Illuminance categories and illuminance values for generic types of activities in interiors

Type of Activity	Ranges of Illuminances Lux	Reference Work-Plane
Public spaces with dark surroundings	20-30-50	
Simple orientation for short temporary visits	50-75-100	General lighting throughout spaces
Working spaces where visual tasks are only occasionally performed	100-150-200	
Performance of visual tasks of high contrast or large size	200-300-500	
Performance of visual tasks of medium contrast or small size	500-750-1000	Illuminance on task
Performance of visual tasks of low contrast or very small size	1000-1500-2000	
Performance of visual tasks of low contrast and very small size over a prolonged period	2000-3000-5000	Illuminance on task, obtained by a combination of general and local (supplementary light)
Performance of very prolonged and exacting visual tasks	5000-7500-10000	
Performance of very special visual tasks of extremely low contrast and small size	10000-15000-20000	

Source: Modified from IES Lighting Handbook: application volume. Kaufman, J.E., editor. Illuminating Engineering Society of North America, 1981. p. 2-5.

To obtain proper light levels, many light fixtures are designed to reflect light off walls, ceilings and objects. The amount of light reflected off a surface can be measured. Suggestions follow for the percentage of light off surfaces in typically reflected offices. The percentage refers to the amount of light that a surface reflects relative to the amount that falls on the surface.



Light fixtures that are too widely spaced or wrongly positioned create shadows. Objects between the light fixture and work block the light and cast shadows. Likewise, workers sitting with their backs to windows, with light fixtures directly overhead or to the rear, cast shadows on their own work surfaces.

Detecting Insufficient Light

- Wipe light fixtures with a damp cloth to check for cleanliness. An evenly deposited film of dust is hard to detect by sight alone.
- Measure the average illumination throughout the workplace. Compare this to the recommended levels.
- Look for shadows, especially over work areas and on stairways.
- Ask workers if they suffer from eye strain or squint to see.

Workers should assume normal working positions during measurement to provide accurate results.

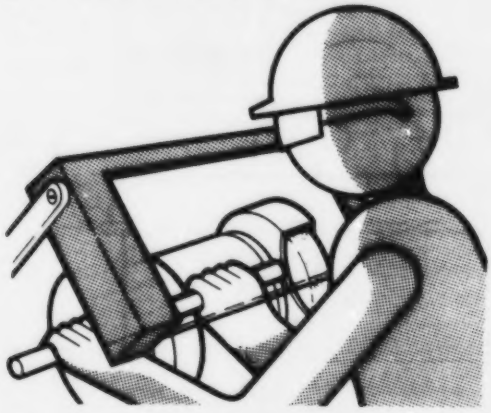
Correcting Insufficient Light

- Add more light fixtures in appropriate places.
- Replace bulbs on a scheduled basis. Old bulbs give less light than new ones, so replace them before they burn out. Follow manufacturers' instructions.

- Clean light fixtures regularly. Dirt on light fixtures reduces the amount of light given off. Light fixtures with open tops allow air currents to move dust up through the fixture so dust and dirt do not accumulate on the fixture.

- Paint walls and ceilings light colours so light can be reflected.

- Use more reflected light and local lighting to eliminate shadows. For example, a covered light mounted under a transparent guard on a grinding wheel provides the added light needed to clearly see the task.

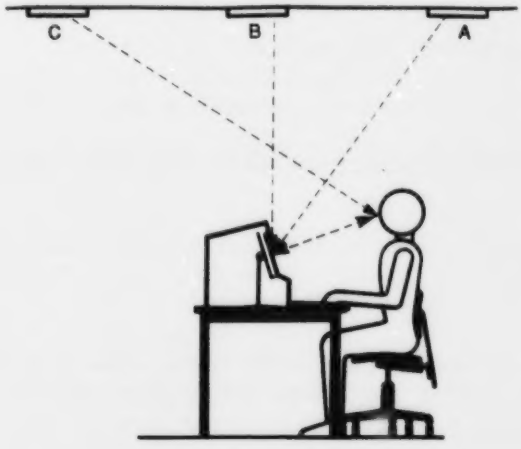


- Do not position work station with light fixture directly behind worker.

Glare

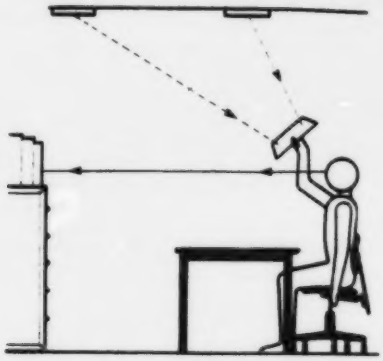
Glare is a common lighting problem. Glare is a sensation produced when the levels of light are sufficiently greater than the level to which the eyes have adapted. Glare can cause annoyance and discomfort and can decrease a person's ability to see while the glare is present.

Light reflected from polished, shiny or glossy surfaces (A, B) causes reflected glare. The glass on picture frames, windows at night and VDT screens are all potential sources of reflected glare. Very bright light from poorly positioned light fixtures (C), or sunlight causes direct glare from too much light entering the eyes.

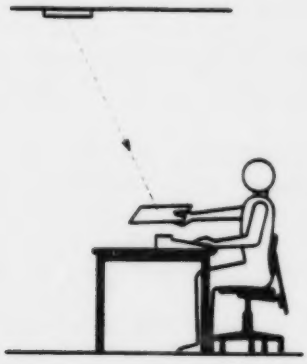


Detecting Glare

- Detect direct glare from the working position by looking at a distant object at eye level. Screen the light fixtures from view. If the distant object is now easier to see, the light fixtures are probably producing glare.



- Detect reflected glare by looking at the task from the normal working position. Block the light falling on it from the front. If details are now easier to see, reflections are a problem.



- Place a small mirror face up on the work surface. The mirror reflects the light fixture responsible for glare.

- Look for shiny objects that reflect light. Glass in picture frames, glossy table tops and VDT screens are common examples.

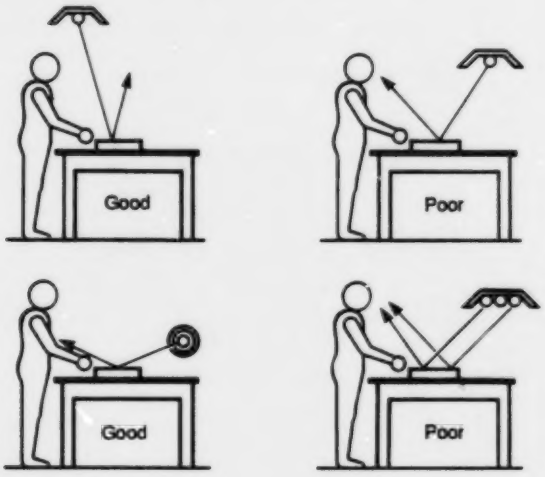
- Ask workers if they experience sore or tired eyes, headaches or if they need to squint to see.

Correcting Glare

- Use several small low-intensity light fixtures rather than one large high-intensity light fixture.

- Use light fixtures that diffuse or concentrate light well. Indirect light fixtures or direct light fixtures with parabolic louvres are two possibilities.

- Cover bare bulbs with louvers, lenses or other devices to control light.
- Increase the brightness of the area around the glare source.
- Use adjustable local lighting with brightness controls.
- Position light fixtures to reduce reflected light that is directed toward the eyes.



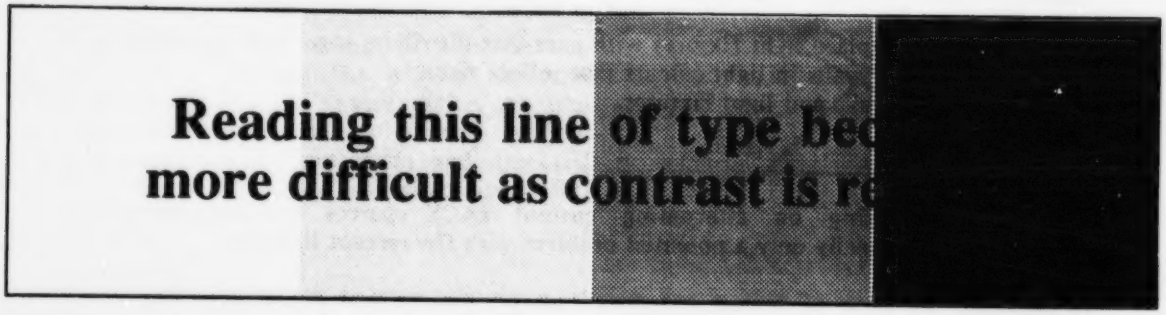
- Use low gloss paper and apply flat or semi-gloss paint and matte finishes to offending surfaces. Remove highly polished and shiny objects. Use anti-glare devices on VDT screens.
- Keep general lighting levels at recommended levels.
- Position the work station so that windows and fluorescent light tubes are parallel to the worker's line of sight.
- Do not position the work station so that light fixtures are to the front or directly overhead.

Improper Contrast

There are two types of contrast problems--the first is very different light levels from one area to another, and the other is contrast between colours of objects.

The immediate work area should be brighter than surrounding areas. If the surrounding area is brighter than the work area, attention is distracted from the work area.

The contrast between colours of objects, such as between print and paper, can cause problems. Too little contrast--between print and the paper or characters on a VDT screen and the background--make reading tasks difficult.



Moving and stationary machine parts are hard to distinguish if they are the same colour.

Detecting Poor Contrast

- Look for great differences in light levels within the workplace.
- Look for objects that are hard to distinguish from the background.
- Look for reading materials and VDTs where it is hard to distinguish print or characters from the background.

Correcting Poor Contrast

- Increase the contrast between objects and the background. Use ink pens rather than pencils, and white paper rather than grey. Adjust photocopier exposure, VDT brightness and contrast controls.
- Decrease reflected glare. Use matte finishes on surfaces and move shiny objects out of view.
- Use contrasting colours for objects and the background. Paint stationary and moving machine parts in contrasting colours to improve visibility and decrease the risk of accident.

Poorly Distributed Light

When light is poorly distributed, parts of the ceiling and general surroundings seem dark and gloomy. Substantial differences in light level, force workers' eyes to readjust when moving from one light level to the other. Workers may find it difficult or impossible to see properly.

Detecting Poorly Distributed Light

- Look for dark areas and uneven lighting.
- Use a light meter to check the illumination at various points throughout the workplace. With uniform general lighting, the minimum reading should not be less than two-thirds of the average value.

Correcting Poorly Distributed Light

- Supplement or replace light fixtures with ones that distribute some light upwards.
- Paint ceiling and walls in light colours that reflect light.
- Clean ceilings, walls and light fixtures.

Flicker

All bulbs operating on alternating current (AC) sources produce pulsating light. Flicker is usually only a potential problem with fluorescent lighting.

In general, the type of ballast has an effect on the amount of flicker. The ballast controls the electrical supply to fluorescent lights. Some types of ballast can reduce flicker considerably.

Side flicker is flicker people see out of the corner of the eye. It is very distracting.

When objects move or rotate in time with the flicker, they are lit at or about the same position during each cycle or rotation. Objects look as if they are moving at speeds other than their actual speeds. Moving objects may even appear stationary. This is the principle behind a strobe light, but it is not the desired effect in general lighting.

Correcting Flicker

- Replace bulbs on a scheduled basis. Old bulbs tend to flicker more and they are not as bright.
- Ensure that all parts of the light fixture, especially the ballast, are functioning properly.

6. A BASIC LIGHTING SURVEY

A complete lighting survey may be needed to identify and solve more subtle or complicated problems. A complete lighting survey requires complex equipment and practical experience.

Follow the manufacturer's instructions for the proper handling, care and maintenance of instruments. Many different techniques and instruments are available. Each of them has its own advantages and disadvantages.

A complete basic lighting survey includes the following:

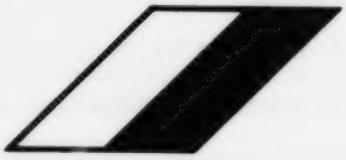
Illuminance

Illuminance is the amount of light falling on a surface. The unit of measurement is lux. A light meter is used to measure it. Readings are taken from several angles and positions.

Luminance

Luminance is the amount of light reflected from a surface. The unit of measurement is candela per square meter. An illuminance meter is used to measure it. Several measurements are made and averaged. Luminance tables are consulted for reference values.

Contrast

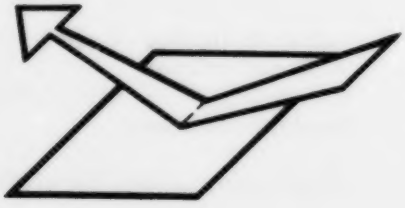


Contrast is the relationship between the brightness of an object and its background. A luminance meter is used to measure it.

The following formula is used to calculate contrast and provides a number between 0 and 1. The average contrast should be above 0.5:

$$\text{Contrast} = \frac{\text{Luminance object - Luminance background}}{\text{Luminance background}}$$

Reflectance



Reflectance is the ratio of light falling on a surface to the light reflected from a surface, expressed as a percentage. A light meter is used to measure it. Reflectance can also be measured using a reflectometer or by comparing the surface of interest with colour chips of known reflectance.

To determine reflectance, the light meter probe is placed on the test surface to measure light falling on the surface. Then place the probe 5-7 cm away facing the surface to measure the light reflected from the surface.

The following formula is used to calculate reflectance:

$$\text{Reflectance (\%)} = \frac{\text{luminance}}{\text{illumination}} \times 100$$

APPENDIX

Lighting Ergonomics - Checklist

Use the checklist. Follow up any "no" answers. A complete lighting survey may be necessary.

General

Enough light for the task. ___

No troublesome reflections. ___

No glare along or near normal line of sight. ___

No frequent visual transition between extremes of light and dark or near and far. ___

Lamps covered to diffuse light evenly. ___

Adequate lighting of upper walls and ceilings. ___

Shadows eliminated. ___

Bright shiny objects out of view. ___

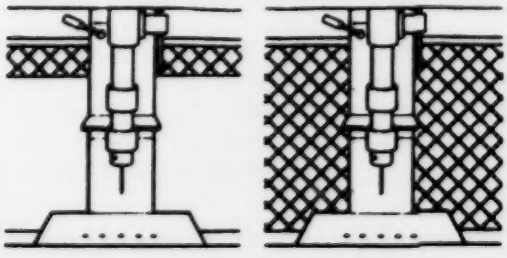
Industry

Very small objects magnified in addition to good lighting. ___

Moving machinery parts painted a colour which contrasts with the background. ___

Adequate lighting in storage rooms, stairways and hallways. ___

Simple background behind tasks. ___



Office

Clear and readable images on VDT. ___

Well-placed local lighting. ___

VDTs positioned parallel to windows. ___

VDTs positioned parallel to fluorescent light fixtures. ___

Matte finishes on furniture and equipment. ___

Blinds or curtains on windows. ___

Brightness and contrast controls properly adjusted on VDTs. ___

Appropriate size print, and good contrast on reading materials. ___

Maintenance

Regular replacement of bulbs. ___

Regular cleaning of light fixtures. ___

Upper walls and ceilings clean. ___

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